MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 3, 2022/2023 (T2230)

ETN4106 – OPTOELECTRONICS AND OPTICAL COMMUNICATIONS

(All Sections/Groups)

5 OCTOBER 2023
9.00 a.m. - 11.00 a.m.
(2 Hours)

INSTRUCTIONS TO STUDENT

1. This question paper consists of **FIVE** printed pages (including the cover page) with **FOUR** questions.
2. Answer **ALL** questions.
3. Write your answers in the Answer Booklet.

Question 1 (25 marks)

Table Q1 shows two characteristics for two types of optical fibers. Answer the following questions based on Table Q1.

Table Q1: Two types of optical fibers and some of its characteristics

Fiber type	Numerical aperture (NA)	Core diameter (μm)
Single mode fiber	0.14	8.2
Multimode fiber	0.20	50.0

(i) Which type of fiber is suitable to be used for an optical fiber link with a length of 100 km? Justify your answer. [1+2 marks]

(ii) Which type of fiber suffers from intermodal dispersion? Justify your answer. [1+2 marks]

(iii) Which type of fiber can efficiently be coupled with a light emitting diode (LED)? Justify your answer. [1+2 marks]

(iv) If the speed of light travelling in the core of the single mode fiber is 2.00×10^8 m/s, what is the core refractive index of the single mode fiber? [2 marks]

(v) Calculate the acceptance angle in water with a refractive index of 1.33 for the single mode fiber and the multimode fiber. Comment on your answer in terms of the acceptance angle for single mode fiber and multimode fiber. [4+1 marks]

(vi) The multimode fiber has a relative refractive index difference of 1%. Calculate the critical angle at the core cladding interface. [3 marks]

(vii) The multimode fiber has a refractive index profile of 2 and is operating at the wavelength of 1310 nm. Determine its normalized frequency (V number). [2 marks]

(viii) Does chromatic dispersion occur in both types of fibers? Justify your answer. Your answer must include a description of why chromatic dispersion occur. [1+3 marks]

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Question 2 (25 marks)

(a) Describe the general requirements for a light source to be used in an optical communication system in terms of its emission wavelength, spectral width and radiance of the source. [6 marks]

(b) Why does a light emitting diode (LED) require less complex drive circuitry compared to a laser diode? [2 marks]

(c) Describe the function of a photodetector in an optical communication system and name **TWO (2)** types of a photodetector that can be used in an optical fiber link. [2+2 marks]

(d) Describe **ONE (1)** method to increase the quantum efficiency of a photodetector. [2 marks]

(e) Does an optical amplifier provide better performance over regenerative repeaters in an optical communication system? Justify your answer with **TWO (2)** reasons. [1+4 marks]

(f) Name **TWO (2)** major types of semiconductor laser amplifiers and compare them in terms of facet reflectivities and resonant type. [6 marks]

Question 3 (25 marks)

(a) With a suitable equation, define signal-to-noise ratio (SNR) at the output of an optical receiver. Your answer must include all the relevant noise sources involved in a photodetector. All the definitions and variables involved must also be included in your answer. [5 marks]

(b) Briefly describe **TWO (2)** ways to improve a system performance in terms of the SNR. [4 marks]

(c) A *pin* photodiode has a capacitance of 2 pF with a post detection bandwidth of 20 MHz in an optical receiver operating at a wavelength of 1550 nm.

(i) Determine the load resistance which allows a post detection bandwidth of 20 MHz. [2 marks]

(ii) If the quantum efficiency of the photodiode is 55% and the incident optical power on the photodiode at the operating wavelength is 1 μW, determine the primary photocurrent generated. [2 marks]

Continued ...

Question 3 (Continued...)

(c) (iii) Determine the rms shot noise current generated in the photodiode. [3 marks]

(iv) If the dark current of the *pin* photodiode is 50 nA, determine the rms dark current noise. [3 marks]

(v) Determine the rms thermal noise current in the load resistor at a temperature of 20°C. [3 marks]

(vi) Determine the signal-to-noise ratio (SNR) in dB at the output of the receiver. [3 marks]

Question 4 (25 marks)

Table Q4 shows the parameters of two designs of an optical fiber link.

Table Q4: Optical fiber link designs A and B

Parameter	Optical Link Design A	Optical Link Design B
Operating wavelength	850 nm	1550 nm
Optical source power	0 dBm	-5 dBm
Photodetector sensitivity	-50 dBm	-45 dBm
Fiber attenuation	3.5 dB/km attenuation at 850 nm	0.2 dB/km attenuation at 1550 nm
Connector loss	0.3 dB/connector	0.1 dB/connector
System margin	5 dB	6 dB

(i) In your opinion, which optical fiber link design is suitable for a long distance communication system and which design is suitable for a short distance communication system? Justify your answer with calculations of the maximum possible transmission distance for both designs A and B. Assume there are 10 connectors being used in both designs. [2+10 marks]

(ii) Suggest **ONE (1)** change in one of the parameters in Table Q4 that can increase the transmission distance for Optical Link Design A. Justify your answer with suitable examples and calculations. The calculations must show that the transmission distance has increased compared to your answer in Question 4 (i). Assume that all other parameters for Optical Link Design A remain the same except the change you suggested to increase the transmission distance. [5 marks]

Continued ...

Question 4 (Continued...)

(iii) After considering some additional losses such as cabled fiber loss and splice loss, the fiber attenuation in Optical Link Design B has increased to 0.6 dB/km. How will this increase in fiber attenuation affect the transmission distance of the link? Justify your answer with suitable calculations and compare your answer to the transmission distance obtained in Question 4 (i). Assume that all other parameters remain the same except for the fiber attenuation. [5 marks]

(iv) Is it important to have a system margin when designing an optical fiber link? Justify your answer. [1+2 marks]

Appendix A

Physical Constants and Units

Constant	Symbol	Value (mks units)
Speed of light in vacuum	c	2.998×10^{8} m/s
Electron charge	e	1.602×10^{-19} C
Boltzmann's constant	k_B	1.38×10^{-23} J/K
Permittivity of free space	ε_0	8.8542×10^{-12} F/m
Permeability of free space	μ_0	$4\pi \times 10^{-7}$ N/A^2
Electron volt	eV	1 eV = 1.602×10^{-19} J
Planck's constant	h	6.626×10^{-34} J·s

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